

Description

CIRCUIT BREAKER COMPRISING AN ELECTRONIC TRIGGER AND
A BYPASS SWITCH

[0001] The invention relates to a circuit breaker, especially for low voltage, comprising an electronic, microprocessor-controlled tripping device and a bypass circuit.

[0002] German patent specification DE 44 45 060 C1 discloses a circuit breaker comprising a bypass circuit (not elaborated upon there), by means of which the circuit breaker is automatically tripped if – for any reason whatsoever – the electronic tripping device does not trip the circuit breaker in spite of the fact that settable parameters have been exceeded, especially the tripping current and the associated delay time.

[0003] German patent application DE 199 27 030 A1 discloses a circuit breaker comprising an electronic, microprocessor-controlled tripping device and a bypass circuit (not elaborated upon there) which serve to effectuate an automatic tripping of the circuit breaker when the preset tripping current has been exceeded without tripping, and also comprising a watchdog circuit to monitor the function of the microprocessor. The bypass circuit is connected to the watchdog circuit and it has switching means (not elaborated upon there) that serve to control the current-dependent and time-dependent response characteristic curve of the bypass circuit as a function of the failure of a functional area of the microprocessor indicated by the watchdog circuit.

[0004] U.S. Pat. No. 5,214,560 discloses a watchdog monitor that functions as a bypass circuit for the microprocessor of the electronic tripping device of a circuit breaker. The monitoring circuit is made up of discrete components and consists of the serial connection of a high pass filter, of a transistor switch, of a timing circuit with a charging capacitor and of a voltage comparator. The properly operating microprocessor continuously emits watchdog pulses via the high pass filter to the transistor switch, whose

output pulses continuously discharge the timing circuit, so that voltage cannot build up in the timing circuit since this could cause the comparator to toggle. If, in contrast, the watchdog pulses are absent due to a failure, then the charging capacitor soon reaches a voltage level that causes the comparator to toggle and, via its output, in turn, a tripping coil becomes excited, as a result of which the circuit breaker opens. A transistor switch arranged at the input of the high pass filter allows the watchdog pulses to be short-circuited so that an error function of the microprocessor can be simulated in order to test the bypass circuit.

[0005] After such a circuit breaker has been switched on, the supply voltage(s) only build(s) up gradually, so that the microprocessor and the bypass circuit can only operate properly after a certain delay. This is particularly disadvantageous if the circuit breaker is switched on during an already existing short circuit, which could have dire consequences for the circuit breaker itself and/or for the systems that are supposed to be protected by the circuit breaker.

[0006] Therefore, the invention is based on the objective of ensuring the protective function of the circuit breaker even when it is switched on during a short circuit.

[0007] On the basis of a circuit breaker of the above-mentioned type, this objective is achieved according to the invention by the features of the independent claim, while the subordinate claims contain advantageous refinements of the invention.

[0008] The invention makes use of the fact that, after the circuit breaker has been switched on, the supply voltage builds up steadily starting at zero up to its final value. At the beginning of this build-up phase, the watchdog circuit is not yet emitting any pulses, while the bypass circuit is already ready to operate at a considerably earlier point in time. As a result, if the circuit breaker is switched on during an already existing short circuit, then the very high test signals emitted by the current detectors as a function of the short circuit situation are processed by the comparator into load pulses for the charging

capacitor, said pulses then causing the tripping coil to be actuated within a very short time. In this process, before the supply voltage exceeds the threshold voltage, the higher, first reference voltage applied to the second comparator input by the monitoring circuit ensures that the circuit breaker is not switched off via the bypass circuit already in case of relatively small overcurrents. During normal operation, if the supply voltage exceeds the threshold voltage, the bypass circuit takes over the monitoring of the watchdog pulses. In the meantime, the lower, second reference voltage applied to the second comparator input ensures that, if the watchdog pulses are absent, the circuit breaker is switched off via the bypass circuit already at moderately overcurrents.

[0009] In an advantageous embodiment of the invention, the first reference voltage corresponds to the maximum settable tripping current, especially the maximum settable short circuit current. In this manner, if the circuit breaker is switched on during a short circuit, the virtually undelayed switching off never takes place below the actually set tripping current. In an advantageous refinement, the reference voltages are switched over by the monitoring circuit after a threshold time that simulates the threshold value of the supply voltage that is normally reached.

[0010] A first pulse shaper stage generates discharge pulses that are to be associated with the watchdog pulses and that are of a sufficient duration to discharge the charging capacitor. A second pulse shaper stage delivers actuation signals of sufficient width, irrespective of the shape of the output signals of the comparator; in this manner, the bypass circuit also responds properly to greatly distorted test signals on the input side since conventional current detectors only deliver greatly shortened test pulses, especially in the case of high short circuit currents.

[0011] In an advantageous manner, the reference voltages are switched over electronically, for example, by means of semiconductor switches. It is advantageous to suppress the watchdog pulses, on the one hand, in order to more reliably prevent a discharge of the charging capacitor in the first phase after the switching on and, on the

other hand, in order to test the bypass circuit by simulating a failure of the microprocessor.

[0012] Additional details and advantages of the invention ensue from the embodiments below explained with reference to the figures. The following is shown:

Figure 1: a schematic depiction of an embodiment of the circuit breaker according to the invention;

Figure 2: examples of pulse diagrams for illustrating how the invention works.

[0013] Figure 1 shows a three-conductor circuit breaker which, via its main contactors 2, connects a consumer 4 to a low-voltage energy source 6. The main contactors 2 are opened and closed by means of actuators 10 that normally have an actuation mechanism 12 and an electromagnetic tripping coil 14. The main current that flows to the consumer 4 via the main contactors 2 is detected by means of current detectors 8, for instance, current transformers or magnetic current sensors. The test signals U_i emitted by the current detectors 8 are fed to an electronic tripping device 20. This electronic tripping device 20 converts the test signals U_i into digital signals by means of an analog-to-digital converter 22 and these signals are then evaluated by a microprocessor 24. If the test signals U_i exceed certain settable parameters, especially the tripping current and the appertaining delay time, then the tripping device 20 sends a first tripping signal U_c to a first OR-input of an actuation circuit 9 in order to excite the tripping coil 14, thus automatically opening the main contactor 2. The microprocessor 24 or the tripping device 20 also encompasses a watchdog circuit 26 which constantly emits watchdog pulses when the microprocessor 24 is operating properly. The test signals U_i are also fed to a supply circuit 30 which uses it to provide a supply voltage U_{cc} that serves to supply energy to the electronic tripping device 20 and to a bypass circuit 40.

[0014] The bypass circuit 40 ensures that, in spite of a failure of the electronic tripping device 20, especially a failure of the microprocessor 24, the main contactors 2 are automatically opened when pre-definable critical currents are exceeded. A conventional high pass filter 41 and a first pulse shaper stage 42 are arranged consecutively in the bypass circuit 40, starting from the watchdog circuit 26. The bypass circuit 40 also contains a monitoring circuit 44, a voltage comparator 45, a charging capacitor 46 and a second pulse shaper stage 43. The high pass filter 41 converts the watchdog pulses present on the input side into needle pulses which, however, are absent if no watchdog pulses are emitted, that is to say, if, due to a malfunction of the microprocessor 24, the watchdog circuit 26 remains constantly at the high level or at the low level on the output side. The needle pulses are converted by the first pulse shaper stage 42 into discharge pulses U_a having a sufficient pulse width.

[0015] A voltage divider 452 feeds the test signals U_i as attenuated test signals U_i' to the first input of the voltage comparator 45. The monitoring circuit 44 monitors the level of the supply voltage U_{cc} emitted by the supply circuit; once the circuit breaker is switched on, this supply voltage U_{cc} increases starting at zero to the final value. The monitoring circuit 44 controls an electronic change-over switch 47. As long as the increasing supply voltage U_{cc} is still below a pre-defined threshold level, a first reference voltage U_{r1} reaches the second input of the comparator 45 via the change-over switch 47 during this initial time interval. In contrast, if the increasing supply voltage U_{cc} exceeds the defined threshold level, then a second reference voltage U_{r2} reaches the second input of the comparator 45 via the change-over switch 47. The first reference voltage U_{r1} is associated with a momentary first current limit value that flows via the main contactors 2 and that is represented by corresponding test signals U_i , said current limit value corresponding to the maximum tripping current that can be set with the electronic tripping device 20, for example, twelve times the rated current for which the circuit breaker is dimensioned. The second reference voltage U_{r2} is considerably less and is associated with a second current limit value that is represented by corresponding test signals U_i , for instance, four times the rated current. Accordingly, during the initial time

interval, the comparator 45 only emits output signals if the attenuated test signals U_i' exceed the first reference voltage U_{r1} . In the period of time following the initial time interval, the comparator 45 already emits output signals if the attenuated test signals U_i' already exceed the lower voltage U_{r2} .

[0016] The output signals of the comparator 45 are picked up by the charging capacitor 46 connected on one side to the reference potential via a charging resistor 462 that is to be provided for this purpose, if necessary. Parallel to the charging capacitor 46, there is a first semiconductor switch 48 whose control electrode is connected to the output of the first pulse shaper stage 42. If discharge pulses U_a are present at this control electrode, then the charging capacitor 46 is short-circuited in sequence with these discharge pulses, and no substantial voltage level can build up via the charging capacitor 46, irrespective of the test signal U_i emitted by the current detectors 8. The clock frequency of the watchdog pulses or of the discharge pulses U_a is several times higher than the mains frequency supplied by the energy source 6. If the discharge pulses U_a are absent due to a failure of the microprocessor 24, then the comparator 45 quickly charges the charging capacitor 46 when corresponding attenuated test signals U_i' occur that exceed the first or second reference voltage U_{r1} or U_{r2} , respectively, that is present at the second comparator input. The slightly delayed voltage pulses that build up via the charging capacitor 46 are processed by a second pulse shaper stage 43 into second tripping signals U_b having a sufficient width which automatically open the main contactors 2 via a second OR-input of the actuation switch 9. Immediately after the circuit breaker has been switched on, only attenuated test signals U_i' that exceed the first reference voltage U_{r1} can lead to the formation of second tripping signals U_b . In contrast, if the supply voltage U_{cc} has exceeded the threshold value, then test signals U_i' that exceed the lower second reference voltage U_{r2} can already lead to the formation of second tripping signals U_b . In contrast, if the discharge pulses U_a are present, then the tripping coil 14 can only be excited by the first tripping signals U_c .

[0017] Between the high pass filter 41 and the first pulse shaper stage 42, there is a second semiconductor switch 49 which, by actuating its control electrode, short-circuits the high pass filter at its output, thereby suppressing the further processing of the watchdog pulses. This can be utilized, on the one hand, to test the proper functioning of the bypass circuit 40 in an operational microprocessor 24. On the other hand, the second semiconductor switch 49 can be employed to prevent the further processing of the watchdog pulses and thus the generation of discharge pulses U_a in the initial time interval from the time when the circuit breaker is switched on until the supply voltage U_{cc} exceeds the threshold voltage. The latter possibility is indicated in Figure 1 by the connection between the monitoring circuit 44 and the second semiconductor switch 49 depicted by the broken line.

[0018] The various ways to trip the circuit breaker of Figure 1 are explained below with respect to the pulse diagrams shown in Figure 2. The individual pulse trains are shown at different scales in Figure 2. In particular, the pulse train of the reference voltage U_r present at the first input of the voltage comparator 45 is depicted at a smaller scale in comparison to the pulse train for the attenuated test signals U_i' at the second input of the comparator 45.

[0019] In the time interval t_0 to t_3 , it is assumed, for example, that the circuit breaker is switched on at the rated current and that an overcurrent occurs considerably later while the electronic tripping device 20 is functioning. The circuit breaker is switched on at the rated current at the point in time t_0 . The attenuated test signals U_i' have a value $U_{n'}$ that corresponds to the rated current. At the point in time t_0 , the supply voltage U_{cc} begins to build up from zero. At a slight delay, the higher, first reference voltage U_{r1} is present as reference voltage U_r at the second input of the voltage comparator 45 and the test signals U_i' do not exceed this first reference voltage U_{r1} . At the point in time t_1 , the supply voltage U_{cc} has exceeded the pre-defined threshold value, so that the reference voltage U_r makes the transition to the lower, second reference voltage U_{r2} . From the point in time t_1 onwards, the electronic tripping device 20 is fully operational. Due to the

emission of watchdog pulses shortly before the point in time t_1 , discharge pulses U_a are then available. Shortly before the point in time t_2 , a test signal U_i occurs that corresponds to the overcurrent that has been set at twice the value of the rated current. Subsequently, at the point in time t_2 , a first tripping signal U_c is generated that automatically opens the main contactor 2 at the point in time t_3 .

[0020] During the time interval t_4 to t_6 , it is assumed, for example, that the circuit breaker is switched on during an already existing short circuit. The circuit breaker is switched on at the point in time t_4 . The attenuated test signals U_i' exceed the first reference voltage U_{r1} that is decisive during the initial time interval, that is to say, twelve times the value U_n' corresponding to the rated current. Subsequently, with a slight delay at the point in time t_5 , a second tripping signal U_b is emitted via the bypass circuit 40 that automatically opens the main contactors 2 at the point in time t_6 . It should be emphasized that the electronic tripping device 20 is still not operational during the time interval t_4 to t_6 .

[0021] In the time interval t_7 to t_{11} , it is assumed, for example, that the circuit breaker is switched on at the rated current and that an overcurrent occurs considerably later while the electronic tripping device 20 has failed. The circuit breaker is switched on at the rated current at the point in time t_7 . At the point in time t_8 , the reference voltage U_r changes from U_{r1} to U_{r2} . It is assumed that the microprocessor 24 fails at the point in time t_9 , as a result of which no more discharge pulses U_a can be generated. Automatic tripping, however, does not yet take place as long as the attenuated test signals U_i' remain below the second reference voltage U_{r2} . Shortly before the point in time t_{10} , however, an attenuated test signal U_i' occurs that is equal to four times the value corresponding to the rated current. Subsequently, at the point in time t_{11} , the bypass circuit 40 generates a second tripping signal U_b .

[0022] The present invention is not restricted to the embodiment described above, but rather, it encompasses all embodiments that have the same effect in the sense of the

invention. Thus, the invention can be configured, for example, in such a way that the switch-over from the first reference voltage U_{r1} to the second reference voltage U_{r2} by the monitoring circuit 44 is not carried out as originally described when the threshold voltage is exceeded by the threshold voltage U_{cc} that is building up, but rather, in a simplified manner, when a defined threshold time is reached. This threshold time is defined such that, from the time when the circuit breaker is switched on until this threshold time, the supply voltage U_{cc} has normally exceeded the threshold value. Naturally, the threshold time has to be defined as a function of the special configuration of the decisive components, particularly the current detectors 8 and the supply circuit 30.